Dry Berth of
Battleship Texas
State Historic Site

Texas Parks and
Wildlife
Department

Battleship TEXAS
Dry Berth Option 5

September 2012

AECOM

Battleship TEXAS Dry Berth Option 5

1 Introduction

Approximately ten months ago, AECOM delivered four viable options for dry-berthing of the Battleship TEXAS. These options had ascribed costs in the range of $38 million to $49 million. However, by directive of the Texas Legislature, an amount of $25 million was specified for the dry-berth project; hence, it was not possible for TPWD to pursue any of these initial four options.

Based on TPWD direction, the consulting team led by AECOM has developed an additional dry berthing option, designated Option 5, which involves grounding the ship in its present location on a sand bed. The main purpose of Option 5 effort was to deliver a viable berthing option that could be pursued at substantially lower cost than the four dry berth alternates previously developed to meet the project's original directives. It is important to note that a grounded mode of support was not envisioned by the original design of the ship, and the 98-year-old battleship is in fragile condition. For this reason, this effort required a Finite Element Model (FEM) analysis to determine the stresses imposed on the ship and settlements resulting from the envisioned grounded berthing of the TEXAS.

2 Features of Option 5

The goal of Option 5 was to allow the ship to be kept in place during and after construction of the dry berth. This would avoid the substantial costs in the previous four options needed to temporarily relocate the ship or to excavate the dry berth in inshore sites. With the ship kept in place and the dry berth constructed on the present wet berth alignment, it is not feasible to construct a pile supported foundation to support the keel block docking layout specified by the ship's designers.

As shown in Figures 1 and 2, the Option 5 scheme consists of:

- Dredging soft sediments from under and around ship
- A sand bed to seat the grounded ship, placed under ship with ship in place
- A cofferdam to the west, to close off the existing basin from the channel
- A dike extension to north and east, connecting to the existing dikes on the south and east
- Revetment slopes all around, with hardscape rip-rap surfacing to resist the effects of the flooding/dewatering cycles envisioned by TPWD
- An access ramp to basin floor for equipment and maintenance
- North ship access ramp/gangway for secondary egress
- Existing features retained:
  - south ramp/gangway
  - monopile moorings
  - south bulkhead

As shown in Figure 3, Option 5 includes the following systems to handle seepage of groundwater and ejection of precipitation:

- Dewatering/drainage system
    - Swale and Catch basins on perimeter at toe of revetment slope
    - Pumpwell at northwest corner, with outfall to channel
- Groundwater collection system
    - Perforated underdrain pipe network in sand feeds to catch basins, which feed to pumpwell
- Site Drainage modifications, as shown in Figure 4, to redirect flows from onshore which now outlet to the basin.

Also shown in Figure 3, a flooding system is provided to allow partial flooding of the basin, a capability requested by TPWD. This system consists of:

- Pumps mounted on cofferdam
- Feed to manifold on top of slope
- Feed to spillway cascading down slope

The proposed sequence for construction of Option 5 would be as follows:

- Perform remedial structural repairs on ship's hull
- Dredge along sides of ship as needed to facilitate scheme.
- Construct cofferdam to elevation +13.5' MLT on west side of existing basin.
- Construct flood protection dike to elevation +13.5' MLT north and east side of basin, connecting to existing south side dike.
- Superflood basin to +12' MLT to raise ship clear of existing bottom; ship remains moored to existing monopiles throughout construction
- Dredge soft sediments from under ship.
- Place sand under the ship and level at approximate elevation -23' MLT.
- Dewater basin, setting ship down on sand bed.
- Construct north access ramp with a pivoted span to accommodate settlement of ship.
- Construct permanent dewatering and flooding systems.
- Construct basin access ramp and side slope finishes.

3 Finite Element Modeling Analysis

The ship's designers considered that the ship would be supported either by buoyancy when afloat or on a specified blocking layout when in dry dock. The grounded mode of support proposed by Option 5 was not envisioned by the original design of the ship. A finite element modeling analysis was conducted to determine the effects which a grounding scheme might have on the ship.

The model incorporates the ship, sand bed and in-situ subsoils in a unified model in order to capture the interaction among them, and resulting stress distributions. The features of the model include:

- Sand modeled using non-linear Drucker-Prager behavior
- Clays modeled using linear properties which change over time
- Model considers a range of soil properties provided by HVJ Associates geotechnical consultants, expressed as lower bound and upper bound values

- Ship hull geometry modeled based on data provided by OTS (Ocean Technical Services) marine surveyors.
- Ship weight and its distribution modeled based on data provided by OTS
- Ship stiffness modeled based on data provided by OTS

The goals of the model were to capture:

- Expected settlements, short term and long term
- Distribution of bearing pressure to ship hull
- Longitudinal bending moments in hull

The most important finding of the analysis is that grounding causes high bending moments in the hull due to its shape and the resulting imprint it makes in the sand. The imprint consists of significant lengths of narrow width towards the bow and stern of the ship, and a relatively short length of large width in the central portion of the ship; see Figure 5. The support provided by the sand, closely related to keel contact width, follows a similar pattern, being large at midship, and small towards the bow and stern. The auxiliary docking keels which extend forward and aft on the bilges, being only 18" wide, tend to slice into the sand, providing no meaningful support. In contrast, the ship's weight distribution is more widespread, with significant portions of the weight located closer to the bow and stern. Moreover, the ship's stern has a large overhang aft of the hull's imprint in the sand. As shown in Figure 6, all this results in a substantial hogging moment, which tensions the main deck and compresses the keel.

For comparison, we analyzed landing the ship on the keel block arrangement specified in the ship's docking plan. The blocking arrangement includes solid blocking towards the bow and stern, and blocks arranged on auxiliary docking keels positioned towards the bow and stern. As shown in Figure 7, we found this to result in a much lower hogging moment.

Based on the ship hull's section modulus as estimated by OTS, the maximum tensile stress in the main deck due to the hogging effect caused by grounding is estimated at approximately 21 ksi, and maximum compressive stress in the keel is about 19 ksi. These are in addition to stresses caused by local effects, such as the spanning of hull plating between frames. These are high stresses, especially for steel produced early last century, and considering the substantial deterioration noted in the OTS survey. In contrast, the tensile stress level in the main deck due to hogging effect is only 4.3 ksi with the ship docked on blocks as originally specified when the ship was designed; the compression stress in the keel is only 3.8 ksi.

These findings indicate the structural integrity of the ship would be compromised by grounding on a sand bed in a dry berth. AECOM did not analyze the partial grounding of the ship in a wet berth, with the ship supported partially by bearing on the ground and partially by buoyancy. However, we would expect that condition to be less severe than grounding in a dry berth, with all support provided by the ground, since the ship's buoyancy is more favorably distributed.

Other findings of the finite element analysis include:

- Predicted settlements: The model was run using a range of soil properties provided by HVJ for the sand bed and the in-situ clay strata below. This produced a large range of settlement predictions. Based on discussion of the result with HVJ, we consider the following predictions of settlement to be most credible:
    - Short term:

    - Due to sand (before grounding ship): 5.5 inches
    - Additional due to ship: 1.3 inches at bow; 3.3 inches at stern
  - Long term (due to sand and ship): 12.1 inches at bow; 14.1 at stern
- Bearing Pressure: Maximum of 4 kips per square foot, occurring at stern

4 Construction Cost Estimates

4.1 Dry Berth

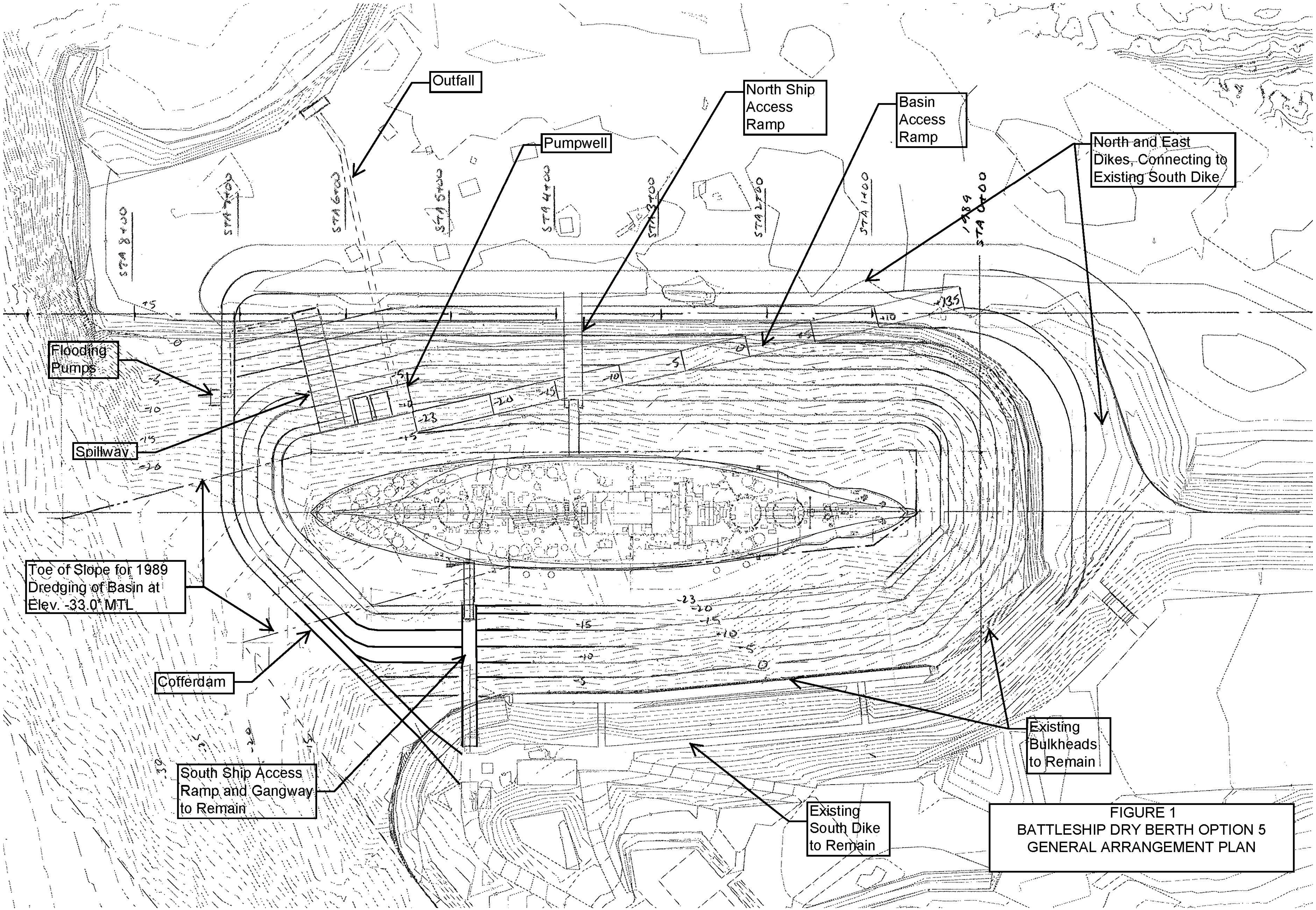
A preliminary cost estimate for the Option 5 dry berth is presented in Appendix A. Including an allowance for contingencies, the cost is about $35 million, less than for the four options previously considered but still in excess of the legislature's $25 million budget. The cost drivers include the need to dredge mud and place sand under the ship, without overhead access for efficient handling of material. Another contributor is the need to hardscape the slopes; the most economic of Options 1-4 used less expensive vegetated slopes.

4.2 Ship Repairs

Determination of the required costs for repair of the Battleship TEXAS was not part of the original effort of developing the first four options, and its impact was hence unknown. To address this, TPWD directed the consulting team to estimate these costs in conjunction with development of Option 5. Consulting team member Joseph Lombardi of OTS conducted a ship condition inspection, and provided a preliminary report and an estimate of ship repairs for Option 5 berthing. The preliminary cost estimate ship repairs, presented in Appendix B, was found to be substantial. It comes in at around $23 million in addition to the cost of a dry berth. This means the combined cost for the Option 5 dry berth plus the necessary ship repair costs for the Battleship TEXAS would total approximately $58 million, well in excess of the available funding.

5 Conclusions

Based on the results of the finite element modeling analysis, the battleship's structural integrity would be unacceptably compromised by grounding the ship on a sand bed in a dry berth as proposed in Option 5. Furthermore, although Option 5 is less costly than the four dry-berthing options initially presented, its cost still exceeds available funding, even before considering ship repair costs. Moreover, considering that the cost of required ship repairs would almost entirely exhaust the available budget, a dry berthing option does not appear feasible within the funding currently available.


Outfall
North Ship Access Ramp
Basin Access Ramp
Pumpwell
North and East Dikes, Connecting to Existing South Dike
Flooding Pumps
Spillway
Toe of Slope for 1989 Dredging of Basin at Elev. -33.0' MTL
Cofferdam
South Ship Access Ramp and Gangway to Remain
Existing South Dike to Remain
Existing Bulkheads to Remain
STA 8+00
STA 7+00
STA 6+00
STA 5+00
STA 4+00
STA 3+00
STA 2+00
STA 1+00
1989 STA 0+00
FIGURE 1
BATTLESHIP DRY BERTH OPTION 5
GENERAL ARRANGEMENT PLAN

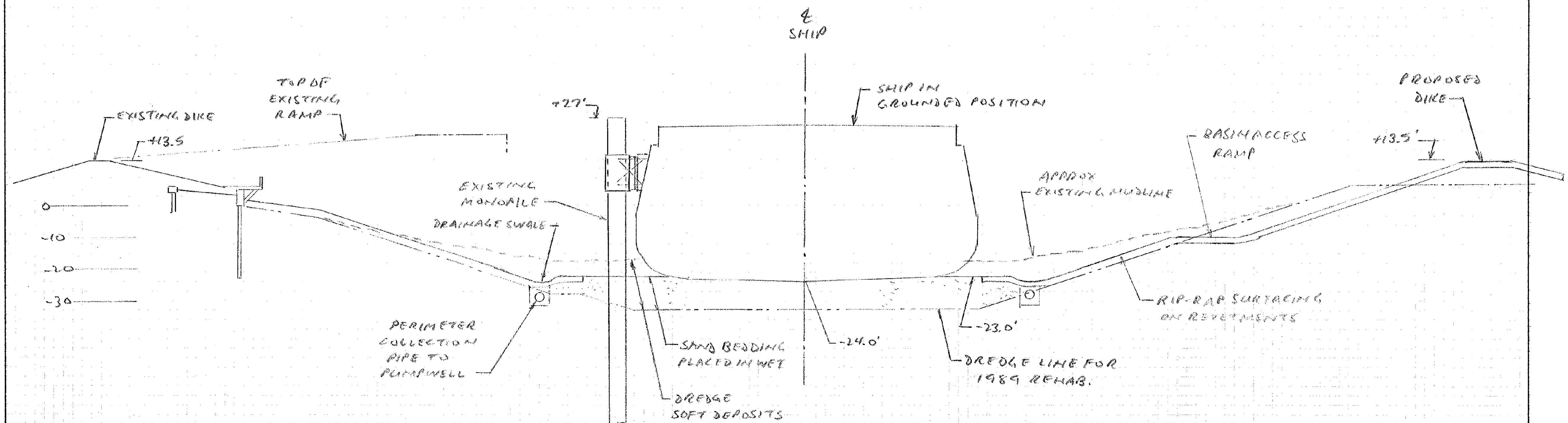


FIGURE 2
BATTLESHIP DRY BERTH OPTION 5
TYPICAL CROSS SECTION

Grid: 10x10 = 1"

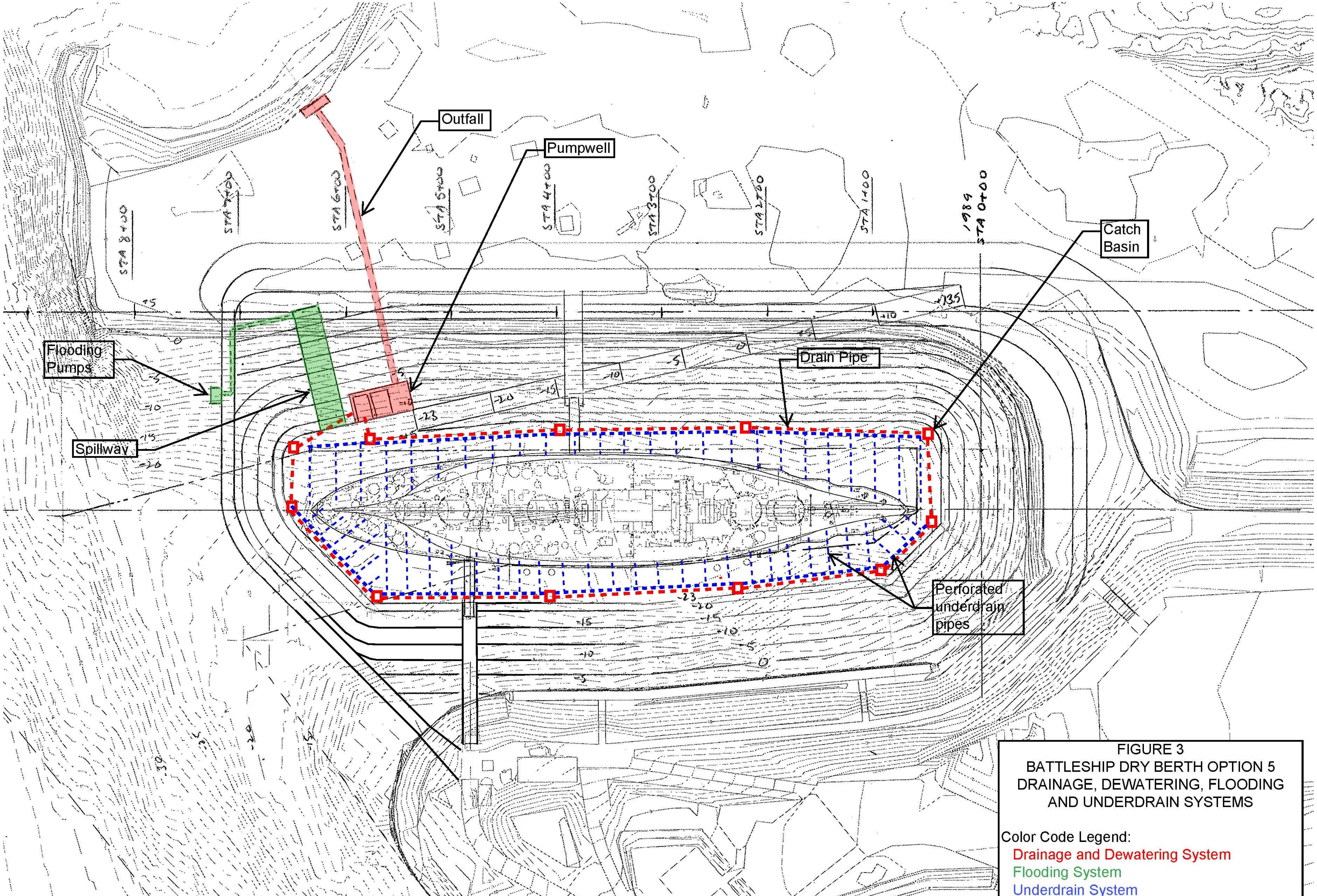


FIGURE 3
BATTLESHIP DRY BERTH OPTION 5
DRAINAGE, DEWATERING, FLOODING AND UNDERDRAIN SYSTEMS

Color Code Legend:
Drainage and Dewatering System
Flooding System
Underdrain System

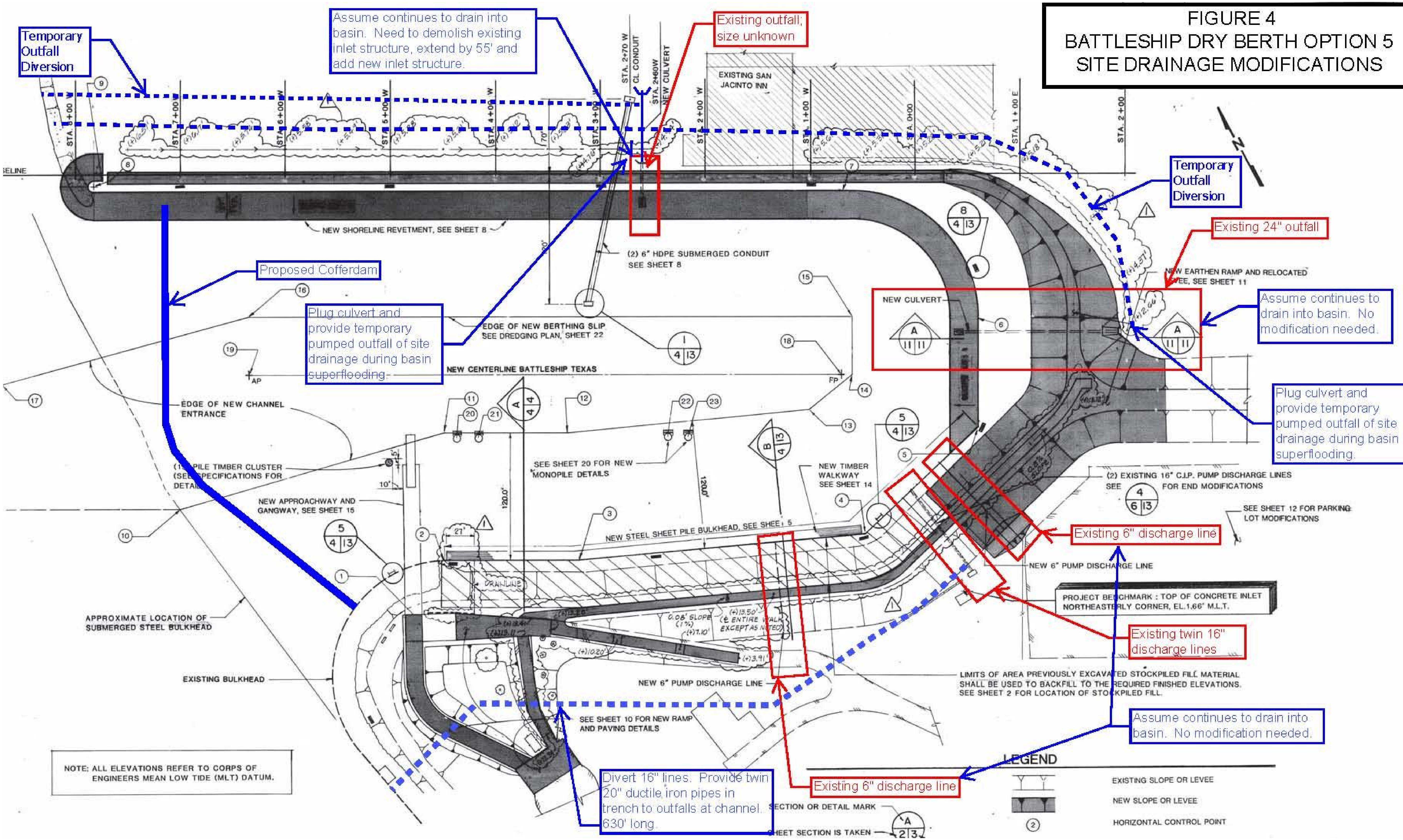


FIGURE 4
BATTLESHIP DRY BERTH OPTION 5
SITE DRAINAGE MODIFICATIONS

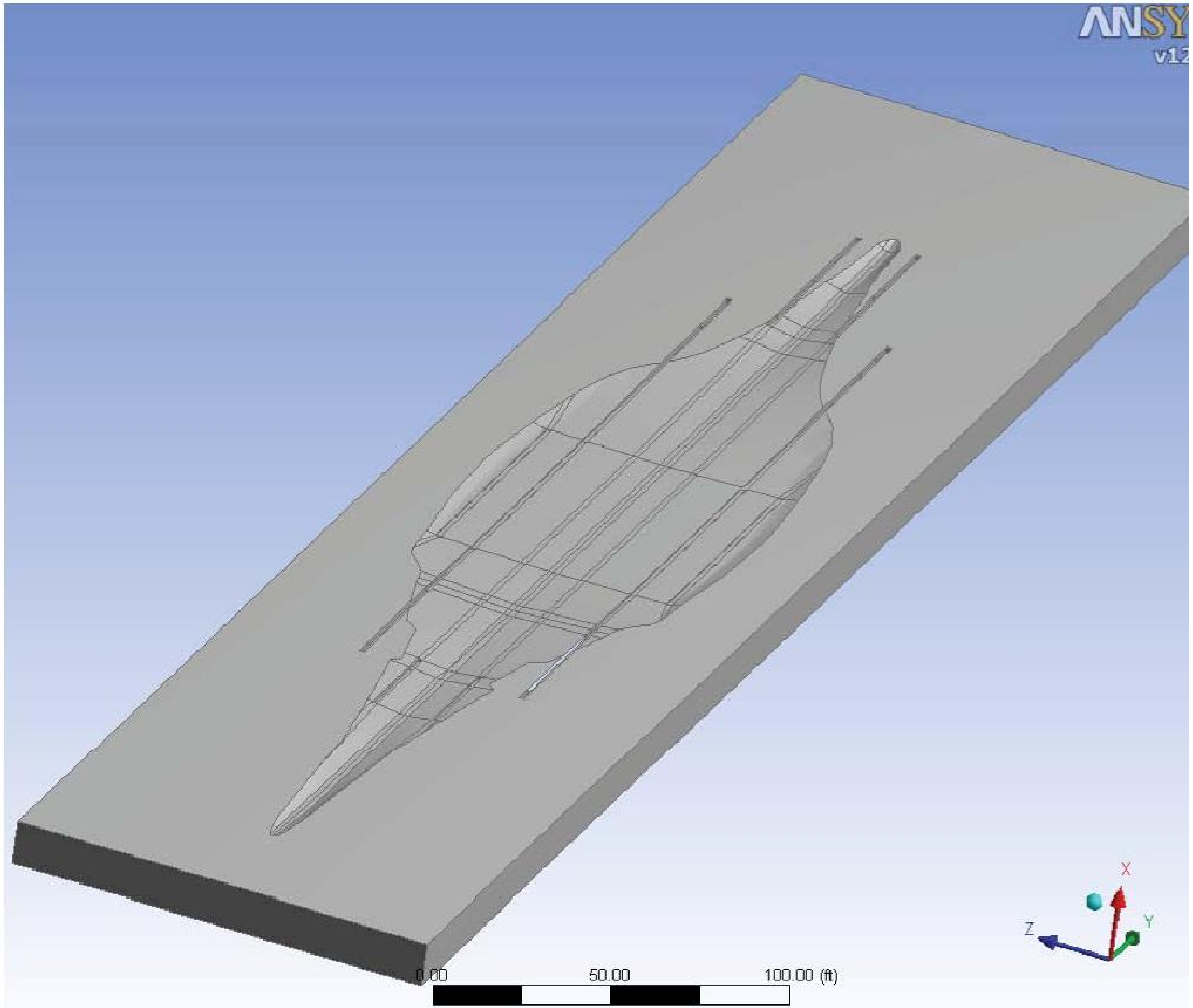


FIGURE 5
HULL IMPRINT IN SAND

AECOM

JOB TITLE	Battleship Texas Dry Berth		
JOB NO.	60188085.Mod 3 - MS	CALCULATION NO.	
ORIGINATOR	JK	DATE 7/26/2012	PRINTED
REVIEWER		DATE	07/31/12
SCALE	N/A	SHEET NO. OF	

L:\60188085 Battleship Texas\400 Technical\407 Structures\407.5 Ship Grounding Analysis\FEM modeling\[Manual Analysis of Ship Bending v5.xlsx]D (2)

Imprint depth: 1.500 feet at FP
2.500 feet 480' aft of FP
Average Bearing Pressure: 2.419 ksf
Bearing Pressure Variation: 0.007 ksf / foot

Bearing Pressure and Bending Moment Calculations: Using defined depth of keel footprint & OTS Hull Geometry

Distance y From FP	Half Width of Footprint (ft)	Width of Footprint (ft)	Length of Strip (ft)	Area of Strip ft^2	Centroid of Strip (ft)	Ay (ft^3)	Moment of Intertia of Strip (ft^4)	Distance from Centroid	Ad^2	Bearing Stress (ksf)	Tributary Reaction (kips)	Applied Loading: Location feet from FP	Applied Loading: Applied Weight Kips	Applied Loading: Applied Weight Kips/ft	Applied Loading: Weight x Location (ft-kips)	Bending Moment (ft-kips)	Bending Stress @ Top (ksi)	Bending Stress @ Bottom (ksi)
																	Positive = Tension	
14.13	0.00	0.0						257.60	0	0.643	0.000						0.000	0.000
28.25	3.60	7.2	14.1	51	23.54	1,199	564	248.18	3,135,865	0.708	36.031	14.125	558.690	19.776	7,892	(7,722)	0.145	(0.130)
42.38	4.48	9.0	14.1	114	35.57	4,063	1,892	236.15	6,370,499	0.791	90.314	14.125	0.000	0.000	0	(14,490)	0.271	(0.243)
56.50	5.50	11.0	14.1	141	49.68	7,008	2,337	222.04	6,954,701	0.888	125.249	42.375	718.299	25.427	30,438	(29,888)	0.560	(0.502)
70.63	6.79	13.6	14.1	174	63.81	11,076	2,876	207.91	7,503,672	0.985	171.040	70.625	1,216.313	43.055	85,902	(43,205)	0.809	(0.726)
84.75	8.06	16.1	14.1	210	77.89	16,330	3,477	193.83	7,877,078	1.082	226.943	70.625	0.000	0.000	0	(70,897)	1.328	(1.191)
113.00	13.29	26.6	28.3	603	100.03	60,311	39,297	171.69	17,773,631	1.235	744.678	98.875	2,531.666	89.616	250,318	(149,082)	2.792	(2.505)
141.25	19.01	38.0	28.3	912	127.96	116,757	60,046	143.76	18,857,604	1.428	1,302.675	127.125	2,980.544	105.506	378,902	(276,437)	5.178	(4.645)
144.00	16.09	32.2	2.8	97	142.59	13,786	61	129.13	1,612,211	1.529	147.786	127.125	0.000	0.000	0	(290,850)	5.448	(4.887)
148.00	17.09	34.2	4.0	133	146.02	19,368	177	125.70	2,095,681	1.552	205.886	127.125	0.000	0.000	0	(311,072)	5.827	(5.227)
152.00	18.18	36.4	4.0	141	150.02	21,156	188	121.70	2,088,618	1.580	222.782	127.125	0.000	0.000	0	(330,438)	6.189	(5.553)
156.00	19.21	38.4	4.0	149	154.02	23,022	199	117.70	2,070,940	1.607	240.263	155.375	4,362.288	154.417	677,790	(351,589)	6.586	(5.908)
159.99	20.19	40.4	4.0	158	158.01	24,888	210	113.71	2,036,476	1.635	257.500	155.375	0.000	0.000	0	(386,472)	7.239	(6.494)
164.01	21.11	42.2	4.0	166	162.01	26,842	222	109.71	1,994,019	1.662	275.438	155.375	0.000	0.000	0	(420,410)	7.875	(7.064)
168.00	26.64	53.3	4.0	191	166.08	31,697	253	105.64	2,129,852	1.691	322.640	155.375	0.000	0.000	0	(453,053)	8.486	(7.613)
172.00	28.28	56.6	4.0	220	170.02	37,325	292	101.70	2,270,546	1.718	377.086	155.375	0.000	0.000	0	(484,280)	9.071	(8.138)
176.00	29.92	59.8	4.0	233	174.02	40,485	310	97.70	2,220,837	1.745	406.029	155.375	0.000	0.000	0	(513,942)	9.627	(8.636)
179.99	31.61	63.2	4.0	246	178.01	43,784	327	93.71	2,159,706	1.773	436.034	155.375	0.000	0.000	0	(541,921)	10.151	(9.106)
184.01	33.12	66.2	4.0	260	182.02	47,262	348	89.70	2,089,439	1.800	467.488	183.625	3,386.958	119.892	621,930	(569,478)	10.667	(9.569)
188.00	34.58	69.2	4.0	271	186.02	50,341	360	85.70	1,987,627	1.828	494.696	183.625	0.000	0.000	0	(607,267)	11.375	(10.204)
192.00	36.10	72.2	4.0	283	190.02	53,687	376	81.70	1,886,096	1.856	524.269	183.625	0.000	0.000	0	(643,019)	12.044	(10.805)
196.00	37.32	74.6	4.0	293	194.01	56,938	391	77.71	1,772,250	1.883	552.648	183.625	0.000	0.000	0	(676,617)	12.674	(11.370)
197.75	35.37	70.7	1.8	127	196.87	25,063	33	74.85	713,338	1.903	242.245	183.625	0.000	0.000	0	(690,638)	12.936	(11.605)
200.00	38.38	76.8	2.2	166	198.89	32,939	70	72.83	878,509	1.917	317.438	183.625	0.000	0.000	0	(707,995)	13.261	(11.897)
226.00	40.47	80.9	26.0	2050	213.11	436,940	115,508	58.61	7,042,353	2.015	4,130.906	211.875	2,926.715	103.601	620,098	(892,889)	16.725	(15.004)
254.25	43.53	87.1	28.3	2373	240.30	570,188	157,737	31.42	2,343,133	2.202	5,225.594	240.125	2,945.183	104.254	707,212	(1,041,340)	19.505	(17.498)
282.50	44.47	88.9	28.3	2486	268.43	667,258	165,314	3.30	26,991	2.396	5,956.511	268.375	2,957.499	104.690	793,719	(1,114,624)	20.878	(18.730)
310.75	43.26	86.5	28.3	2478	296.56	734,938	164,803	(24.84)	1,529,057	2.590	6,419.016	296.625	2,945.976	104.282	873,850	(1,095,773)	20.525	(18.413)
339.00	40.73	81.5	28.3	2373	324.73	770,445	157,739	(53.01)	6,667,683	2.784	6,606.217	324.875	3,162.174	111.935	1,027,311	(978,698)	18.332	(16.446)
367.25	34.73	69.5	28.3	2132	352.75	751,982	141,475	(81.03)	13,997,048	2.978	6,347.599	353.125	4,666.959	165.202	1,648,020	(787,800)	14.756	(13.238)
395.99	21.59	43.2	28.7	1619	380.50	615,984	109,439	(108.78)	19,157,347	3.169	5,130.158	381.375	4,782.443	169.290	1,823,904	(562,270)	10.532	(9.448)
400.01	19.88	39.8	4.0	166	397.97	66,197	223	(126.25)	2,651,314	3.289	547.148	381.375	0.000	0.000	0	(529,621)	9.920	(8.900)
404.00	18.40	36.8	4.0	153	401.98	61,505	204	(130.26)	2,596,086	3.317	507.529	381.375	0.000	0.000	0	(494,981)	9.271	(8.318)
408.00	17.12	34.2	4.0	142	405.98	57,638	189	(134.26)	2,559,069	3.345	474.847	381.375	0.000	0.000	0	(458,380)	8.586	(7.702)
412.00	15.96	31.9	4.0	132	409.98	54,207	176	(138.26)	2,527,320	3.372	445.870	409.625	4,617.854	163.464	1,891,588	(430,897)	8.071	(7.241)
416.00	14.91	29.8	4.0	123	413.97	51,080	164	(142.25)	2,496,932	3.400	419.497	409.625	0.000	0.000	0	(409,187)	7.664	(6.876)
420.01	13.80	27.6	4.0	115	417.98	48,141	154	(146.25)	2,463,699	3.427	394.754	409.625	0.000	0.000	0	(385,766)	7.226	(6.482)
424.00	13.06	26.1	4.0	107	421.99	45,311	143	(150.27)	2,424,534	3.455	370.982	409.625	0.000	0.000	0	(360,901)	6.760	(6.064)
428.00	12.26	24.5	4.0	101	425.98	43,118	135	(154.26)	2,408,681	3.483	352.503	409.625	0.000	0.000	0	(334,589)	6.267	(5.622)
432.00	11.53	23.1	4.0	95	429.98	40,902	127	(158.26)	2,382,537	3.510	333.905	409.625	0.000	0.000	0	(306,905)	5.749	(5.157)
436.00	10.87	21.7	4.0	90	433.98	38,864	119	(162.26)	2,357,704	3.538	316.811	409.625	0.000	0.000	0	(277,922)	5.206	(4.670)
439.99	10.27	20.5	4.0	84	437.98	37,000	112	(166.26)	2,335,062	3.565	301.188	437.875	3,880.032	137.346	1,698,969	(255,925)	4.794	(4.300)
444.01	9.94	19.9	4.0	81	441.99	35,819	109	(170.27)	2,349,496	3.593	291.177	437.875	0.000	0.000	0	(239,979)	4.495	(4.033)
448.00	9.88	19.8	4.0	79	446.00	35,321	105	(174.28)	2,405,488	3.621	286.736	437.875	0.000	0.000	0	(222,937)	4.176	(3.746)
452.00	7.90	15.8	4.0	71	449.93	31,973	94	(178.21)	2,256,764	3.648	259.210	437.875	0.000	0.000	0	(204,785)	3.836	(3.441)
480.25	4.77	9.5	28.3	358	464.96	166,461	23,325	(193.24)	13,368,844	3.751	1,343.012	466.125	3,110.697	110.113	1,449,974	(96,385)	1.805	(1.620)
505.75	4.77	9.5	25.5	243	493.00	119,942	13,183	(221.28)	11,912,528	3.945	959.692	494.375	2,282.040	80.780	1,128,184	(36,207)	0.678	(0.608)
530.00												522.625	950.956	33.662	496,993	(5,009)	0.094	(0.084)
560												550.875	624.734		344,150	8,032	(0.150)	0.135
											55,608.020	297.747	55,608		16,557,145			

Extended stem per docking plan

$$y = yA \;/\; A$$

ΣyA = 6,246,541 ft^3
ΣA = 22,989 ft^2 — 32,639 ft^2 as measured
ybar= 271.72 feet from FP
Front of Footprint: 28.00 feet from FP — Cf= 243.720 feet
Rear of Footprint: 541.00 feet from FP — Ca= 269.280 feet
Frame 49: 196.00 feet from FP — C49= 75.720 feet
Frame 95: 380.00 feet from FP — C95= 108.280 feet

Section Modulii of Midship Cross Section

$$I = \Sigma A d^2$$

At Top: 53,387.6 ft-in^2
At Bottom: 59,510.5 ft-in^2
Bending Stresses: 20.878 ksi maximum at top
(18.730) ksi maximum at bottom

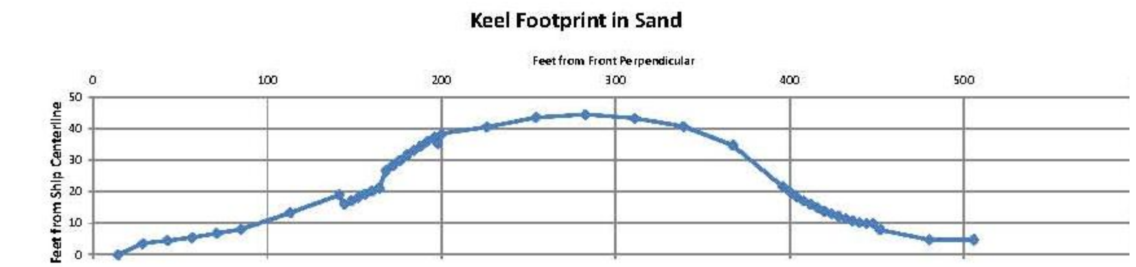
Moment of Inertia = 209,903,749 ft^4

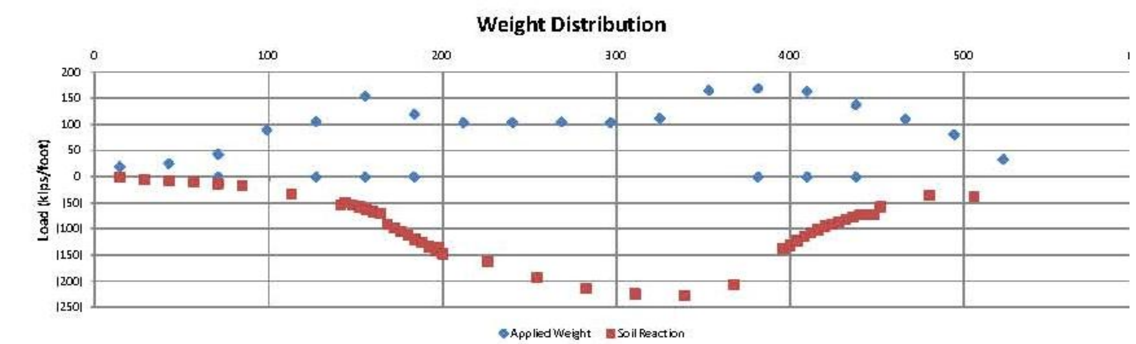
Weight Distribution per Naval Architect

CG= 297.747 feet from FP
Ship Weight P= 24,825 LT
= 55,608 kips
e= 26.027 feet
σ_f= 0.023 ksf
σ_a= 3.560 ksf
σ_{49}= 1.182 ksf
σ_{95}= 2.450 ksf

$$\sigma_f = \frac{P}{A} - \frac{PeC_f}{I}$$

$$\sigma_a = \frac{P}{A} + \frac{PeC_a}{I}$$





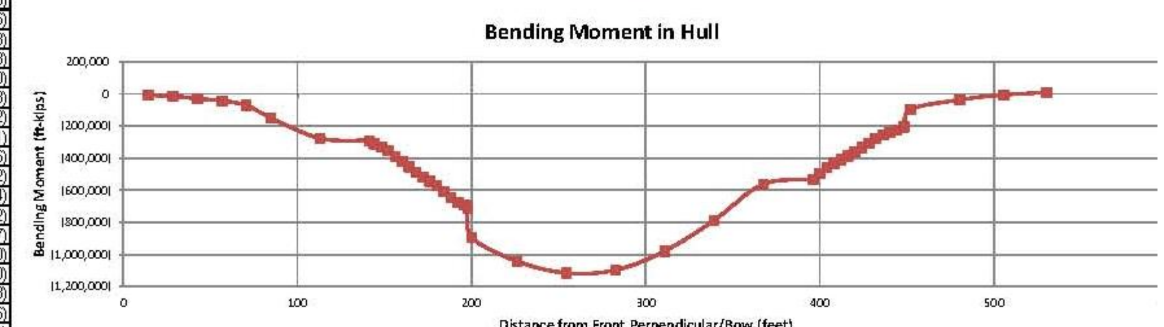


FIGURE 6

ANALYSIS OF HULL SUPPORTED ON SAND

AECOM	JOB TITLE	Battleship Texas Dry Berth			
	JOB NO.	60188085.Mod 3 - MS	CALCULATION NO.		
	ORIGINATOR	JR	DATE	7/27/2012	PRINTED
	REVIEWER		DATE		07/31/12
	SCALE	N/A	SHEET NO.	OF	

L:\60188085 Battleship Texas\400 Technical\407 Structures\407.5 Ship Grounding Analysis\FEM modeling\[Manual Analysis of Ship Bending v5.xlsx]Docking Keels

Bearing Pressure and Bending Moment Calculation: Ship on Docking Keels

Docking Keel Geometry

	Distance from FP, feet				Block		Length	Center y	Effective Area	Effective Moment of	Ay	d	Ad^2
	Start	End	Width (in)	Density	Type	Remarks	feet	feet	ft^2	Inertia ft^4	ft^3	feet	ft^4
Centerline	27.000	466.417	48.000	0.583	Spaced	14" blocks spaced at 24"	439.417	246.708	1,025.306	16,497,765	252,951	(31.753)	1,033,774.4
	466.417	505.750	48.000	1.000	Solid		39.333	486.083	157.333	20,284	76,477	207.622	6,782,144.4
First offset, forward	88.417	103.417	36.000	1.000	Solid	Width = 18" port + 18" starboard	15.000	95.917	45.000	844	4,316	(182.545)	1,499,516.8
	103.417	147.000	36.000	0.583	Spaced		43.583	125.208	76.271	12,073	9,550	(153.253)	1,791,336.1
First offset, aft	411.000	452.667	36.000	0.583	Spaced	Width = 18" port + 18" starboard	41.667	431.834	72.917	10,550	31,488	153.372	1,715,231.6
	452.667	467.667	36.000	1.000	Solid		15.000	460.167	45.000	844	20,708	181.706	1,485,761.0
Second offset	143.000	158.000	36.000	1.000	Solid	Width = 18" port + 18" starboard	15.000	150.500	45.000	844	6,773	(127.961)	736,835.9
	158.000	401.000	36.000	0.583	Spaced		243.000	279.500	425.250	2,092,549	118,857	1.039	458.7
	401.000	416.000	36.000	1.000	Solid		15.000	408.500	45.000	844	18,383	130.039	760,951.2
Third offset	226.000	241.000	36.000	1.000	Solid	Width = 18" port + 18" starboard	15.000	233.500	45.000	844	10,508	(44.961)	90,968.9
	241.000	315.000	36.000	0.583	Spaced		74.000	278.000	129.500	59,095	36,001	(0.461)	27.6
	315.000	330.000	36.000	1.000	Solid		15.000	322.500	45.000	844	14,513	44.039	87,272.8
								278.461	2,156.577	18,697,379	600,524		15,984,279

Applied Load 55,608 kips

Centered at 297.747 feet aft of FP

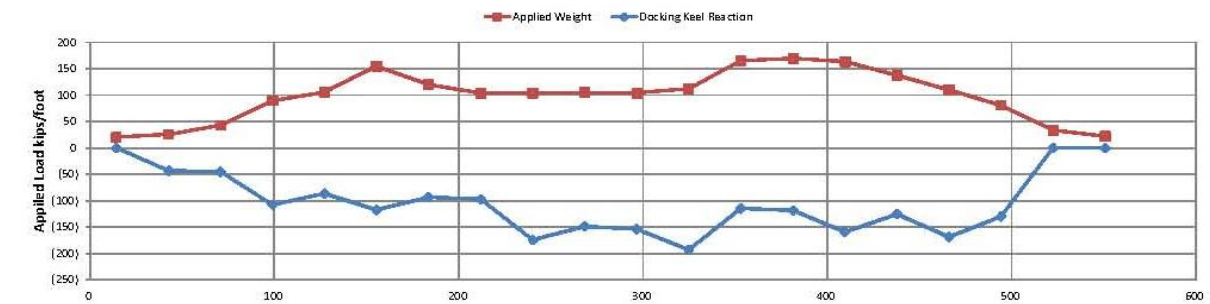
Eccentricity 19.286 feet aft of FP

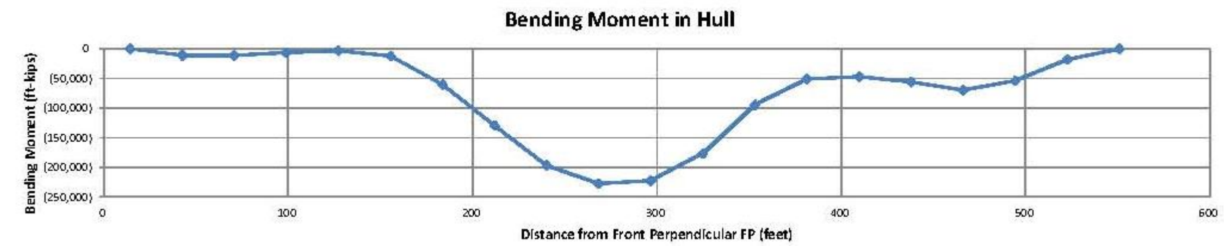
Average Bearing Pressure: 25.785 ksf

Bearing Pressure Variation: 0.031 ksf / foot

Total Effective Area= 2,157 ft^2

Total Effective Moment of Inertia= 34,681,658 ft^4





	Distance from FP, feet		Bearing Pressure (ksf)		Line Load (kips / ft)											
						Location x (feet)	14.125	42.375	70.625	98.875	127.125	155.375	183.625	211.875	240.125	268.375
						Applied Weight (kips)	559	718	1,216	2,532	2,981	4,362	3,387	2,927	2,945	2,957
	Start	End	Start	End	Start	End	Line Load Intensities (kips/ft) at or forward of Location x:									
Centerline	27.000	466.417	18.009	31.597	42.022	73.727	0.000	43.131	45.170	47.208	49.246	51.285	53.323	55.361	57.400	59.438
	466.417	505.750	31.597	32.814	126.390	131.255	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
First offset, forward	88.417	103.417	19.909	20.372	59.726	61.117	0.000	0.000	0.000	60.696	61.117	61.117	61.117	61.117	61.117	61.117
	103.417	147.000	20.372	21.720	35.652	38.010	0.000	0.000	0.000	0.000	36.935	38.010	38.010	38.010	38.010	38.010
First offset, aft	411.000	452.667	29.884	31.172	52.297	54.551	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	452.667	467.667	31.172	31.636	93.517	94.908	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Second offset	143.000	158.000	21.596	22.060	64.789	66.181	0.000	0.000	0.000	0.000	0.000	65.937	66.181	66.181	66.181	66.181
	158.000	401.000	22.060	29.575	38.606	51.755	0.000	0.000	0.000	0.000	0.000	0.000	39.992	41.521	43.050	44.578
	401.000	416.000	29.575	30.038	88.724	90.115	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Third offset	226.000	241.000	24.163	24.627	72.489	73.881	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	73.800	73.881
	241.000	315.000	24.627	26.915	43.097	47.102	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	44.578
	315.000	330.000	26.915	27.379	80.746	82.137	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Location x (feet)	296.625	324.875	353.125	381.375	409.625	437.875	466.125	494.375	522.625	550.875
Applied Weight (kips)	2,946	3,162	4,667	4,782	4,618	3,880	3,111	2,282	951	625
Centerline	61.476	63.515	65.553	67.591	69.630	71.668	73.706	73.727	73.727	73.727
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	129.848	131.255	131.255
First offset, forward	61.117	61.117	61.117	61.117	61.117	61.117	61.117	61.117	61.117	61.117
	38.010	38.010	38.010	38.010	38.010	38.010	38.010	38.010	38.010	38.010
First offset, aft	0.000	0.000	0.000	0.000	0.000	53.751	54.551	54.551	54.551	54.551
	0.000	0.000	0.000	0.000	0.000	0.000	94.765	94.908	94.908	94.908
Second offset	66.181	66.181	66.181	66.181	66.181	66.181	66.181	66.181	66.181	66.181
	46.107	47.636	49.165	50.693	51.755	51.755	51.755	51.755	51.755	51.755
	0.000	0.000	0.000	0.000	89.524	90.115	90.115	90.115	90.115	90.115
Third offset	73.881	73.881	73.881	73.881	73.881	73.881	73.881	73.881	73.881	73.881
	46.107	47.102	47.102	47.102	47.102	47.102	47.102	47.102	47.102	47.102
	0.000	81.662	82.137	82.137	82.137	82.137	82.137	82.137	82.137	82.137

Bending Moment Effects (ft-kips) of Block Support Reactions

Location x (feet)	14.125	42.375	70.625	98.875	127.125	155.375	183.625	211.875	240.125	268.375
Bending Effect of Centerline Blocks	0	5,011	40,985	113,008	222,706	371,706	561,633	794,116	1,070,781	1,393,254
	0	0	0	0	0	0	0	0	0	0
Beding Effect of First offset row of forward blocks	0	0	0	3,284	28,259	53,862	79,466	105,070	130,673	156,277
	0	0	0	0	10,140	48,051	93,398	138,746	184,093	229,440
Bending Effect of First offset row of aft blocks	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
Bending Effect of Second offset row of blocks	0	0	0	0	0	4,990	32,512	60,261	88,011	115,760
	0	0	0	0	0	0	12,827	57,437	135,183	247,286
	0	0	0	0	0	0	0	0	0	0
Bending Effect of Third offset row of blocks	0	0	0	0	0	0	0	0	7,275	38,259
	0	0	0	0	0	0	0	0	0	16,333
	0	0	0	0	0	0	0	0	0	0
Bending Effect of Applied Loads	0	(15,783)	(51,858)	(122,293)	(264,249)	(490,404)	(839,795)	(1,284,867)	(1,812,618)	(2,423,571)
Net Bending Moment (ft-kips)	0	(10,772)	(10,872)	(6,001)	(3,144)	(11,795)	(59,959)	(129,237)	(196,602)	(226,961)
Bending Stress at Top (ksi)		0.202	0.204	0.112	0.059	0.221	1.123	2.421	3.683	4.251
Bending Stress at Bottom (ksi)		(0.181)	(0.183)	(0.101)	(0.053)	(0.198)	(1.008)	(2.172)	(3.304)	(3.814)

Location x (feet)	296.625	324.875	353.125	381.375	409.625	437.875	466.125	494.375	522.625	550.875
Bending Effect of Centerline Blocks	1,763,163	2,182,133	2,651,792	3,173,767	3,749,683	4,381,168	5,069,849	5,788,274	6,506,702	7,225,130
	0	0	0	0	0	0	0	49,848	184,530	327,673
Beding Effect of First offset row of forward blocks	181,880	207,484	233,088	258,691	284,295	309,899	335,502	361,106	386,709	412,313
	274,788	320,135	365,483	410,830	456,178	501,525	546,872	592,220	637,567	682,915
Bending Effect of First offset row of aft blocks	0	0	0	0	0	19,061	76,007	138,892	201,777	264,662
	0	0	0	0	0	0	8,506	48,316	88,239	128,161
Bending Effect of Second offset row of blocks	143,509	171,259	199,008	226,757	254,507	282,256	310,005	337,755	365,504	393,253
	394,966	579,441	801,934	1,063,662	1,363,917	1,674,070	1,984,223	2,294,376	2,604,528	2,914,681
	0	0	0	0	3,310	39,374	77,266	115,157	153,049	190,940
Bending Effect of Third offset row of blocks	69,271	100,283	131,295	162,307	193,319	224,331	255,344	286,356	317,368	348,380
	68,227	154,611	248,891	343,171	437,451	531,732	626,012	720,292	814,572	908,852
	0	3,952	37,386	71,897	106,408	140,918	175,429	209,940	244,451	278,961
Bending Effect of Applied Loads	(3,118,074)	(3,895,800)	(4,762,857)	(5,761,757)	(6,895,760)	(8,160,218)	(9,534,286)	(10,996,232)	(12,522,645)	(14,075,923)
Net Bending Moment (ft-kips)	(222,270)	(176,502)	(93,981)	(50,674)	(46,693)	(55,883)	(69,271)	(53,701)	(17,649)	0
Bending Stress at Top (ksi)	4.163	3.306	1.760	0.949	0.875	1.047	1.298	1.006	0.331	0.000
Bending Stress at Bottom (ksi)	(3.735)	(2.966)	(1.579)	(0.852)	(0.785)	(0.939)	(1.164)	(0.902)	(0.297)	0.000

Section Modulii of Midship Cross Section

At Top: 53,387.6 $ft\text{-}in^2$

At Bottom: 59,510.5 $ft\text{-}in^2$

Bending Stresses: 4.251 ksi maximum at top

(3.814) ksi maximum at bottom

FIGURE 7

ANALYSIS OF HULL SUPPORTED ON BLOCKS

APPENDIX A
Dry Berth Construction
Cost Estimate

Construction Stages

Option 5 Construction Cost Estimate

1 Before Cofferdam	2 Build Cofferdam	3 Basin Superflooded	4 Basin Dewatered	Item Description	Unit	Quantity	Unit Cost	Cost
				Dredging and Removals:				
			X	Remove existing revetment armoring	SF	30,240	$1.87	$56,549
				Dredging before cofferdam construction				
X				Dredging mobilization/demobilization	LS	1	$150,292	$150,292
X				Dredging for wet berth formation	CY	48,176	$18.13	$873,423
				Dredging under ship after cofferdam construction				
		X		Dredging mobilization/demobilization	LS	1	$68,904.00	$68,904
		X		Dredging for wet berth formation	CY	25,824	$99.77	$2,576,505
X		X		Dredge material transport, placement fee and testing	CY	74,000	$21.34	$1,579,160
				Superflooding				
	X			Supply temporary pumps for superflooding	LS	1	$27,004.00	$27,004
		X		Maintain superflood elevation	Months	6	$53,328.00	$319,968
		X		Plug existing 24" outfalls	EA	2	$455.44	$911
		X		Supply temporary pumps for site drainage	EA	2	$14,622.90	$29,246
		X		Outfall hoses for diverted site drainage	LF	1,701	$26.86	$45,689
			X	Excavation in dry for basin formation	CY	7,156	$6.05	$43,292
			X	Disposed unused excavated fill	CY	7,156	$17.13	$122,582
				1.0 Total				**$5,893,524**
				Dry Berth Wall Construction:				
				West Cofferdam				
	X			King pile cantilever cofferdam wall	LF	485	$14,414.32	$6,990,945
	X			Promenade on top of wall	LF	485	$653.11	$316,758
	X			Concrete fill in King Pile cavities	CY	1,438	$175.58	$252,559
			X	Sand Fill placed in dry	CY	3,741	$27.45	$102,697
			X	Access ramp on grade				
			X	Paving	SF	9,653	$2.88	$27,799
			X	Guard rails	LF	536	$25.00	$13,406
				Landscaping				
			X	Rip-rap on slopes	CY	9,207	$66.05	$608,120
			X	Filter stone under rip rap	CY	3,453	$42.19	$145,666
			X	Filter fabric under filter stone	SF	186,441	$0.28	$52,204
			X	Boulders on Curbline	LF	1,390	$24.47	$34,013
				Spillway				
			X	Floor	SF	2,319	$16.98	$39,377
			X	Walls	CY	69	$734.64	$50,881
				Temporary dewatering system for construction				
		X		Dewater dry berth basin for construction	LS	1	$37,918.46	$37,918
			X	Maintain dry basin	Months	6	$19,063.14	$114,379
				North & East Dike				
	X			Fill	CY	12,317	$25.28	$311,376
			X	Paving	SF	25,100	$2.82	$70,782
				2.0 Total				**$9,168,881**

Construction Stages

Option 5 Construction Cost Estimate

1 Before Cofferdam	2 Build Cofferdam	3 Basin Superflooded	4 Basin Dewatered	Item Description	Unit	Quantity	Unit Cost	Cost
				Dry Berth Floor Construction:				
				Sand bed				
		X		Sand bed under ship	CY	17,216	$61.25	$1,054,498
		X		Sand bed beyond ship	CY	22,415	$43.27	$969,910
				Perimeter Surfacing				
			X	Articulated concrete block surfacing	SF	31,000	$9.57	$296,670
			X	Filter fabric	SF	31,000	$0.06	$1,860
				Underdrain System				
			X	8" perforated header pipes	LF	1,245	$11.85	$14,753
			X	6" perforated lateral pipes	LF	2,047	$36.96	$75,657
			X	Trenching	CY	607		INCL
			X	Crushed stone backfill	CY	303		INCL
			X	Filter fabric	SF	16,376		INCL
			X	Cleanouts for underdrains	EA	62	$172.38	$10,688
				Catch basins				
			X	Type 1: 48" ID, 5" wall, 12" floor	EA	9	$3,594.61	$32,351
			X	Type 2: 60" ID, 6" wall, 12" floor	EA	2	$4,615.33	$9,231
			X	Inlet grates and frames	EA	11	$841.80	$9,260
			X	Access ladder rungs	EA	50	$65.28	$3,264
				Drainage Piping				
			X	15" RCP	LF	150	$77.56	$11,634
			X	18" RCP	LF	340	$87.63	$29,794
			X	21" RCP	LF	335	$99.09	$33,195
			X	24" RCP	LF	520	$110.04	$57,221
			X	30" RCP	LF	80	$170.93	$13,674
			X	Trenching	CY	1,397		INCL
			X	Crushed stone backfill	CY	1,005		INCL
			X	Filter fabric	SF	19,121		INCL
			X	Temporary Construction Access Ramp	LS	1		INCL
				3.0 Total				**$2,623,661**

Construction Stages

Option 5 Construction Cost Estimate

1 Before Cofferdam	2 Build Cofferdam	3 Basin Superflooded	4 Basin Dewatered	Item Description	Unit	Quantity	Unit Cost	Cost
				Dewatering and Flooding Systems:				
				Pumpwell Structure:				
			X	Excavation	CY	1,506	$37.65	$56,701
			X	Temporary Sheeting	SF	6,760	$40.77	$275,605
			X	Backfill	CY	564	$23.98	$13,525
			X	Crushed Stone Base	CY	99	$41.72	$4,130
			X	Concrete Floor (24-in)	CY	96	$410.41	$39,399
			X	Concrete Floor (18-in)	CY	28	$435.81	$12,203
			X	Concrete Walls	CY	223	$990.55	$220,893
			X	Concrete Roof	CY	30	$906.17	$27,185
			X	Steel roof framing	Ton	3	$6,057.63	$18,173
			X	Steel roof grating	SF	800	$35.17	$28,136
			X	Watertight access covers	EA	3	$961.13	$2,883
			X	Access ladder rungs	EA	40	$78.85	$3,154
			X	Watertight access door	EA	1	$7,377.65	$7,378
				Pumpwell Plumbing:				
			X	Submersible pumps, 2,800 gpm	EA	3	$60,428.65	$181,286
			X	Sump pump	EA	1	$4,918.00	$4,918
			X	12" check valves	EA	3	$5,037.87	$15,114
			X	12" gate valves	EA	3	$7,137.87	$21,414
			X	12" piping	LF	90	$255.21	$22,969
			X	12" elbows	EA	3	$1,005.37	$3,016
			X	24" tees	EA	3	$6,579.07	$19,737
			X	24" elbows	EA	2	$4,286.30	$8,573
			X	24" piping	LF	9	$937.50	$8,438
			X	24" to 12" reducers	EA	3	$5,047.32	$15,142
				Outfall:				
	X		X	24" piping (buried)	LF	280	$399.44	$111,843
			X	24" Tideflex	EA	1	$7,203.58	$7,204
			X	Trenching	CY	207		INCL
			X	Backfill	CY	175		INCL
	X			Concrete headwall structure	CY	4	$762.95	$2,967
				Flooding System:				
	X			Vertical turbine pumps, 2,800 GPM	EA	2	$95,115.00	$190,230
	X			18" piping (hung off inside face of cofferdam)	LF	160	$648.15	$103,704
	X			Manifold chamber	LS	1	$7,293.42	$7,293
				Electrical:				
			X	Dewatering system control panel	LS	1	$58,039.00	$58,039
	X			Flooding system control panel	LS	1	$47,039.00	$47,039
			X	Underwater cable and conduit	LF	330	$69.55	$22,952
			X	Allowance for Inst & Control Conduit (DW System)	LS	1	$42,514.00	$42,514
	X			Above-ground conduit and wiring	LF	480	$64.51	$30,965
			X	Allowance for Inst & Control Conduit (Flood System)	LS	1	$42,514.00	$42,514
			X	Control building	LS	1	$48,360.00	$48,360
			X	Emergency Generator	LS	1	$114,005.00	$114,005
				4.0 Total				**$1,839,599**

Construction Stages

Option 5 Construction Cost Estimate

1 Before Cofferdam	2 Build Cofferdam	3 Basin Superflooded	4 Basin Dewatered	Item Description	Unit	Quantity	Unit Cost	Cost
				Site Improvements:				
X			X	Protect electrical ship service cables on north side	EA	1	$36,079.00	$36,079
				North Access Ramp & Gangway				
			X	Piles	LF	720	$67.12	$48,326
			X	Pile Caps	CY	29	$1,491.56	$43,255
			X	Girder Spans	SF	2,027	$42.44	$86,026
			X	Curbs	LF	281	$37.42	$10,515
			X	Landing Stem Wall	CY	3	$1,090.00	$3,270
			X	Abutment	CY	7	$985.16	$6,896
			X	Landing Slab	CY	4	$1,600.00	$6,400
			X	Guardrails	LF	281	$105.00	$29,505
			X	Steel Gangway	EA	1	$86,657.00	$86,657
			X	Gangway Support on Ship	EA	1	$12,937.00	$12,937
X				Redirect twin 16" drain pipes to channel	LF	630	$302.97	$190,871
				Extend 24" culvert to channel				
X				Demolish existing inlet structure	LS	1	$680.00	$680
X				Contruct new inlet structure	LS	1	$3,052.00	$3,052
X				Extend 24" culvert thru new dike	LF	55	$154.63	$8,505
				5.0 Total				**$572,974**
				Total Direct Cost				**$20,098,639**
				General Conditions / Job Indirects (10%)	LS			$2,009,864
				SUB TOTAL				**$22,108,503**
				OH & P - 19.27%				$4,260,308
				SUB TOTAL				**$26,368,811**
				Contingency Costs (20%)				$5,273,762
				Engineering, Geotech Testing, CM				$3,164,257
				TOTAL COST				**$34,806,831**

APPENDIX B

Ship Repair

Cost Estimate

ITEM	PRELIMINARY COST ESTIMATE SUMMARY- OPTION 5 SHIP REPAIRS	Figure #	COST	PERCENT
1	**Boiler Rooms B3 & B 4, Frames 60 ½ - 77 ½**	**2/1**	$ 1,379,718.00	10%
2	**Port & Starboard , Reserve Feed Water Tanks (B-3-4-W, B-3-3-W, B-4-2-W, B-4-3-W)**	**4/1**	947,200.00	7%
3	**Engine Rooms (C-1 & C-2)**	**2/1**	1,556,076.00	11%
4	**Emergency Fuel Tanks (C-94F,C-95F, C-96F, C-97F, C-98F, C-99F)**	**5/1**	5,979,600.00	42%
5	**Keel Vertical Flat Plating (Frames 89-104)**	**1**	503,400.00	4%
6	**Aft Emergency Diesel Generating Room (D-11) & Void Tank D-99V Under D-11**	**4/1**	1,077,515.00	8%
7	**Trimming Tanks (D-12 & D-13) & D-27 Steering Gear Room**	**3/1**	1,640,995.00	12%
8	**Void Tanks (D-107, D-101, D-102, D-103)**	**1**	792,150.00	6%
9	**CPO (Berthing D-111, Mess D-112, Pantry D-113)**	**1**	300,940.00	2%
10	**Total**		$ 14,177,594.00	100%
11	**General Contractor Equipment & Supervision**		565,500	
12	**Contractor mob/demob with 40’ x 110’ spud barge, 100 ton crane, 35 ton crane, pusher tug, two 200 kw generators, one flatbed trailer, one Hyster fork truck, six welding machines, six oxy/acetylene units, one contractor trailer, power, phones, two Porti-Pottis**		450,000.00	
13	**General Liability Insurance**		55,000.00	
14	**Builder’s Risk Insurance**		32,500.00	
15	**Total**		$ 15,280,594	
16	**Bonds (2%)**		305,612.00	
17	**Total**		$ 15,586,206	
18	**Profit & Overhead 15%**		2,337,931.00	
19	**Total Cost of Repairs**		$ 17,924,137	
20	**Total Cost of Repairs (Rounded)**		$ 18,000,000.00	
21	**Contingincies @ 20%**		3,600,000.00	
22	**Engineering & CM @ 8%**		1,440,000.00	
23	**Grand Total (Rounded)**		$ 23,000,000.00	

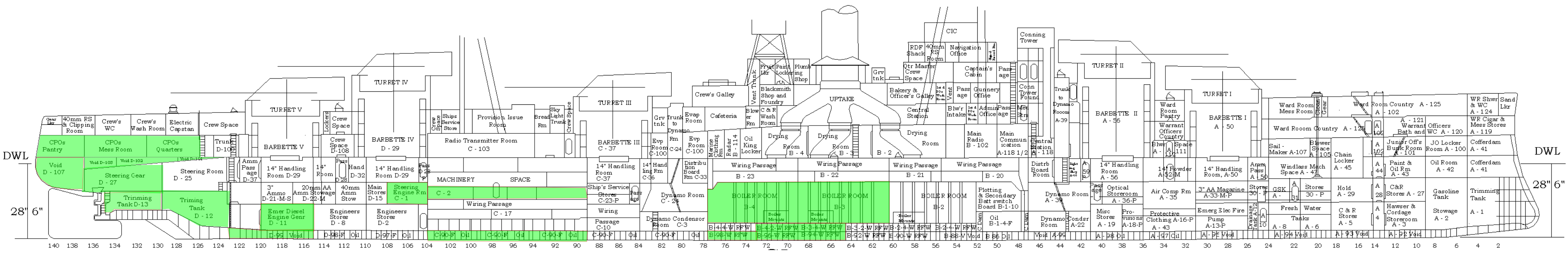


FIGURE B1: TEXAS CROSS-SECTION SHOWING SHIP REPAIR AREAS

FIRST PLATFORM

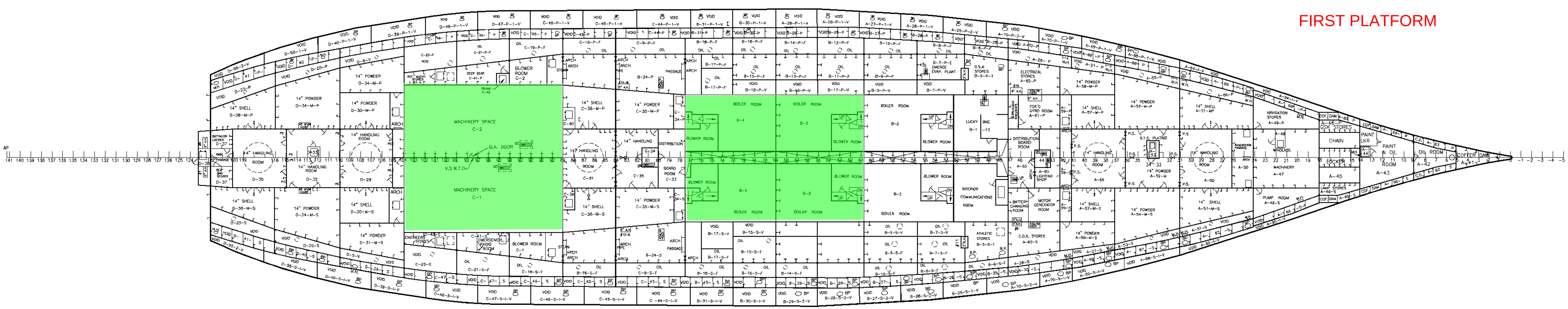


FIGURE B2: BOILER ROOMS B-3/B-4 & ENGINE ROOMS C-1/C-2

SECOND PLATFORM

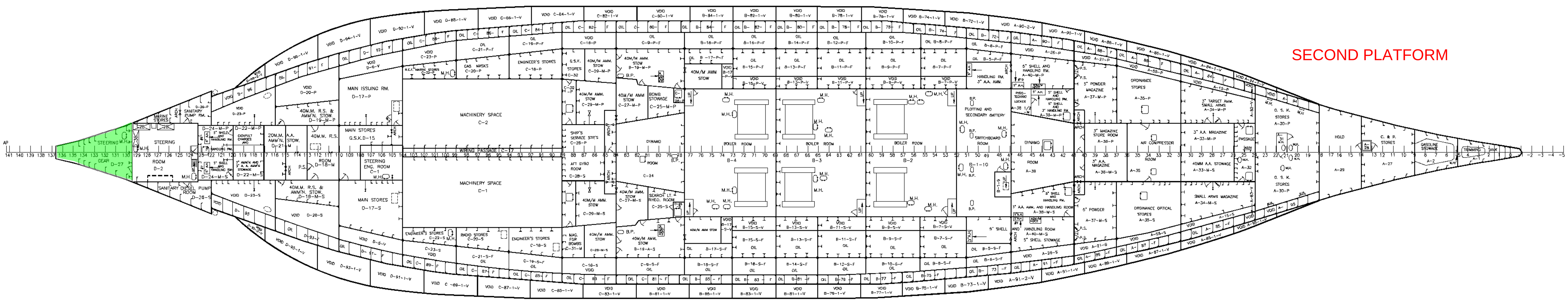


FIGURE B3: TRIMMING TANKS & STEERING GEAR ROOMS

HOLD

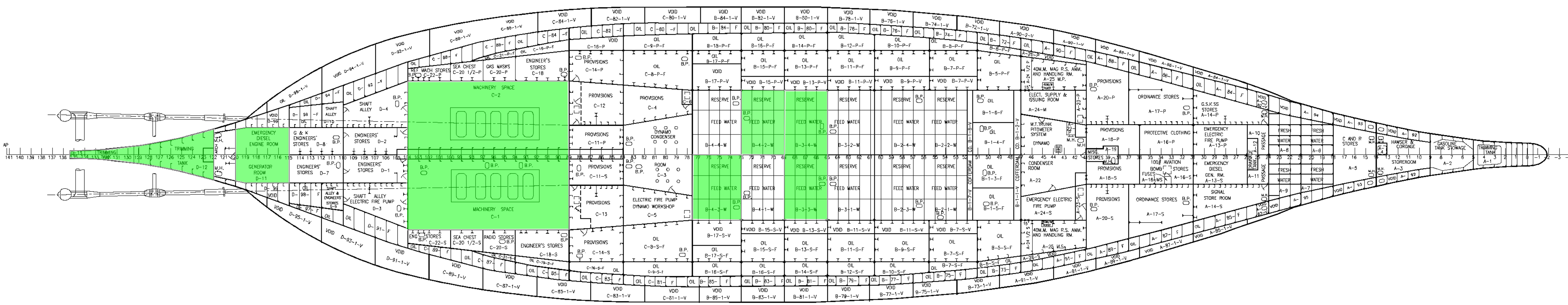


FIGURE B4: RESERVE FEED WATER & TRIMMING TANKS

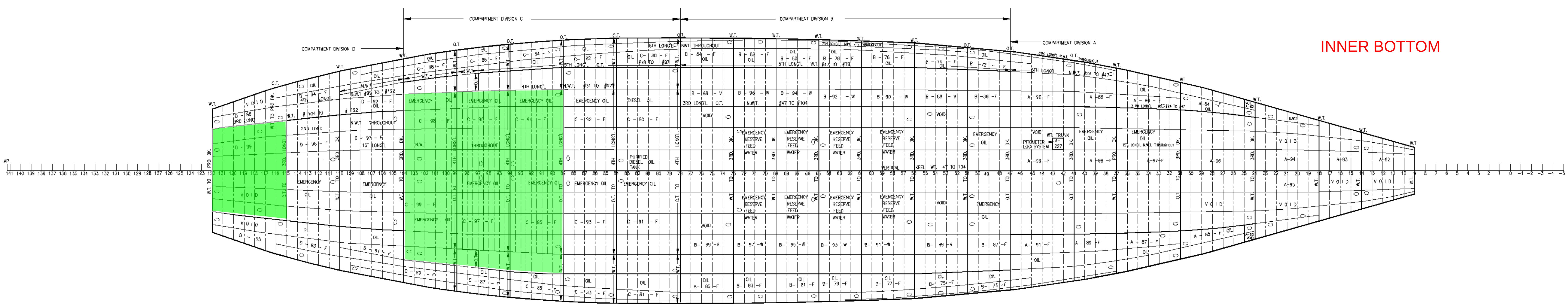


FIGURE B5: EMERGENCY FUEL TANKS & VOID TANK D-99V